



**CONTROL OF POSTHARVEST BROWN ROT  
OF SWEET CHERRIES AND PEACHES  
WITH CHEMICAL AND HEAT TREATMENTS**

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# CONTROL OF POSTHARVEST BROWN ROT OF SWEET CHERRIES AND PEACHES WITH CHEMICAL AND HEAT TREATMENTS

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## SUMMARY

Hot-water and hot-air treatments effectively controlled decay in sweet cherries and peaches. Treating in 125° F. water for 2.5 minutes or 115° water for 5 minutes decreased the percentage of decayed fruit with almost equal effectiveness. Treatment in 115° water for 2.5 minutes was somewhat less effective. The addition of 100 p.p.m. methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate (benomyl) to 115° water was more effective in controlling decay of cherries than treatment in 115° water only for a 2.5-minute exposure.

Injury sometimes occurred on fruit exposed to air near 100 percent relative humidity at 125° F. for 30 minutes and to fruit dipped in suspensions of benomyl in 125° water. Exposing fruit to 105° air of high relative humidity for 24 hours controlled decay about as effectively as the best of the brief hot-water treatments. When the relative humidity during the 105° exposure was high (85 to 95 percent), decay was less prevalent than when it was low (37 percent). Peaches exposed 24 hours to 105° air of high relative humidity ripened normally at 65°; those exposed to 105° air of low relative humidity were badly shriveled.

## INTRODUCTION

Brown rot, caused by *Monilina fructicola* (Wint.) Honey, is a serious postharvest disease of sweet cherries and peaches. Fruits may be infected in the orchard before harvest or in contaminated containers or packing houses after harvest. Control of this disease,

therefore, cannot depend on proper orchard practices alone. After harvest, low-temperature refrigeration, chemical treatments, and heat treatments are the principal methods for controlling decay of most produce. Both postharvest chemical and heat treatments and a combination of the two have been extensively tested to control postharvest decay of peaches (2, 3, 4, 5, 6, 10, 11, 13, 15, 16, 17, 19, 20, 21).<sup>1</sup> With sweet cherries, decay is controlled mainly by low-temperature refrigeration or high concentrations of carbon dioxide (1, 7, 8). Postharvest chemical treatments of cherries have been tried only to a limited extent (12, 14). To date, no publications on heat treatments to control postharvest decays of this fruit are known.

In the United States, heat treatments to control postharvest decays of peaches and other fruits have been limited mostly to hot-water treatments or heated chemical suspensions (15, 17, 20, 21). In Australia, on the other hand, exposing peaches to 105° F. air for 24 hours is the major heat treatment tested (9, 18) and used commercially. This study compares the effectiveness of unheated and heated suspensions of chemicals with hot-water or hot-air treatments to control decay in sweet cherries and of hot-water or hot-air treatments to control decay in peaches.

## MATERIALS AND METHODS

'Royal Anne', 'Cumberland', and 'Windsor' sweet cherries, grown commercially in Maryland, were used in most of these tests. At harvest many of these fruits had numerous splits or cracks and some of them had been injured by hail. Since such fruit could not be evaluated accurately for injury due to treatment, 'Bing' cherries from Washington and Oregon, free of injury, were used for these tests. Duplicate lots of 25 cherries each were used for each treatment in all tests.

'Sunhaven', 'Redhaven', 'Blake', 'Sunhigh', and 'Loring' peaches, obtained from commercial orchards in Maryland and Virginia, were used in these tests. All fruit were sorted before the tests for uniformity of size and freedom from diseases or other blemishes. Twenty fruit were used per treatment in all except one test in which 15 fruit were used.

Both cherries and peaches were inoculated 24 hours before treatment by dipping the fruit into a beef-peptone broth suspension containing about  $9 \times 10^4$  *Monilinia* spores per milliliter. Peaches were also inoculated with *Rhizopus stolon-*

<sup>1</sup> Italic numbers in parentheses refer to Literature Cited, p. 11.

*ifer* (Ehr ex. Fr.) Vuill. by dipping them into a suspension containing about  $21 \times 10^4$  spores per milliliter. Neither the cherries nor peaches were artificially injured before inoculation with *Monilinia* spores, but a shallow cut, resembling fingernail injury, was made on each cheek of peaches inoculated with *Rhizopus* spores. After inoculation all fruits were held at 65° F.

For treatments, fruits were submerged into a constant temperature hot-water bath at 115° F. for 2.5 or 5 minutes or at 125° for 2.5 minutes. In addition, cherries were treated with suspensions of methyl 1-(butylcarbamoyl)-2-benzimidazole-carbamate (benomyl) at 100 and 500 p.p.m. in 70° water and at 100 p.p.m. in 115° and 125° water.

Fruits were also treated with hot air. Some were placed in a closed glass chamber and high-humidity air (95 to 100 percent) constantly circulated around them. Temperature within the glass chamber was maintained at 115° or 125° F. with 15- or 30-minute exposures. Others were held at 105° for 24 hours in metal drums sealed with glass lids. Relative humidity (RH) within a drum was controlled with a lithium chloride electric hygrometer in conjunction with a humidistat. Desired relative humidities within the different drums were 75, 85, and 95 percent. To obtain these relative humidities, a pump circulated air through heated water and into the respective drum when the relative humidity within that drum was below the setting of the humidistat. A second pump added dry air when the relative humidity was at, or above, the desired setting. The relative humidity level in each drum was monitored at intervals and at the end of each test by plugging the lithium chloride saturated element into a hygrometer indicator. In each test, an additional lot of peaches was placed at the ambient relative humidity of the 105° room.

In the test chambers the pulp and subsurface temperatures of the fruit were measured at intervals by thermocouples embedded near the pit or just under the skin of the peaches. These thermocouples were connected to a 24-point temperature recorder. Temperatures of fruit in the ambient air were taken with thermocouples at the end of the tests.

Both cherries and peaches were held at 65° F. and about 90 percent relative humidity after treatment. Six separate tests were conducted with cherries and eight with peaches. All data on decay were analyzed by the analysis of variance and the means were compared by using the Duncan Multiple-Range Test.

The effect of the various treatments on softening of peaches was determined in five tests by using the Magness-Taylor pressure tester with a 5/16-inch plunger.

## RESULTS

### Decay of Cherries due to *Monilinia*

After 3 days at 65° F., a very low percentage of decay developed on untreated cherries (dry or wet checks) and none on the treated fruit.

After 6 and 9 days at 65° F., a high percentage of the untreated fruit developed brown rot (table 1). At each reading period decay of fruit given each of the treatments was significantly less than that of either check. Differences in decay developing on cherries treated with 100 or 500 p.p.m. benomyl were not significant. Cherries treated with heated suspensions of benomyl usually developed significantly less decay than those treated with unheated suspensions. When benomyl was added to 115° water and the fruit given 2.5-minute exposure, less decay developed on the cherries than on those treated with 115° water only. Fruit given the other hot-benomyl treatments and that treated with 115° water for 5 minutes or 125° water for 2.5 minutes developed about the same percentage of decay. Decay of cherries given the hot-air treatments did not differ significantly from those treated with hot water for 6 days after treatment. However, after 9 days at 65° most of the hot-water treated cherries developed less decay than the hot-air treated fruit.

### Injury to Cherries

All cherries, treated and untreated, showed some degree of injury after 6 or 9 days at 65° F. The injury developed as small, round, slightly sunken areas giving the severely injured fruit a stippled appearance. Sometimes the skin was bleached. This injury was more severe on locally grown cherries that were injured before harvest than on the western grown Bing cherries. Locally grown fruit treated in 115° water for 5 minutes, and in 125° water with or without benomyl for 2.5 minutes, and in 125° air for 30 minutes had the most severe injury. All locally grown varieties had about the same degree of injury from the heat treatments. Bing cherries treated in 125° air were severely injured and unsalable. Somewhat less severe injury developed in Bing cherries treated in 115° water for 5 minutes, 125° water with benomyl, and 105° air and 80 percent relative humidity for 24 hours. Injury on the Bing

Table 1.—Decay at 65° F. of sweet cherries inoculated with *Monilinia fructicola* spores 24 hours before treatment<sup>1</sup>

Postharvest treatment	Decay during—	
	6 days	9 days
	<i>Percent</i>	<i>Percent</i>
<b>Checks:</b>		
Dry (no treatment) . . . . .	74.3a	83.0a
Wet (70° F. water) . . . . .	71.0a	85.0a
<b>Benomyl treatment, 70° F. water—</b>		
500 p.p.m . . . . .	15.5 bcd	31.7 bcde
100 p.p.m . . . . .	27.0 bc	41.7 bc
<b><i>Hot-water treatments</i></b>		
<b>115° F. water for—</b>		
2.5 min.:		
Water only . . . . .	29.7 b	51.7 b
Plus benomyl 100 p.p.m. . . . .	7.0 d	19.8 def
5.0 min.:		
Water only . . . . .	1.3 d	11.7 ef
Plus benomyl 100 p.p.m . . . . .	2.3 d	8.3 f
<b>125° water for 2.5 min.:</b>		
Water only . . . . .	1.3 d	5.3 f
Plus benomyl 100 p.p.m . . . . .	2.0 d	2.7 f
<b><i>Hot-air treatments</i></b>		
115° F. air, 95 pct. RH, for 30 min . .	9.0 cd	29.3 cde
125° F. air, 95 pct. RH, for 30 min . .	8.3 cd	38.0 bcd
<b>105° F. air for 24 hours</b>		
<b>and relative humidity<sup>2</sup>—</b>		
80 pct . . . . .	9.3 cd	46.7 bc
89 pct . . . . .	6.7 d	39.0 bcd
97 pct . . . . .	16.3 bcd	39.7 bcd

<sup>1</sup> Mean of 6 tests of duplicate lots of 25 cherries each. Means are compared by the Duncan Multiple-Range Test. In the individual columns, means followed by a letter or letters in common are not significantly different at the 5-percent level.

<sup>2</sup> Readings on relative humidity made with a hygrometer indicator.



cherries receiving the other treatments did not differ significantly from that on wet or dry checks.

### Decay of Peaches

All of the treated fruit developed less monilinia and rhizopus decay than the untreated fruit (wet and dry checks) during the first 3 days at 65° F. (tables 2 and 3). Decay developing on fruit with each of the heat treatments was about equal. After 6 days

Table 2.—Decay at 65° F. of peaches inoculated with *Monilinia fructicola* spores 24 hours before treatment<sup>1</sup>

Postharvest treatment	Decay during—	
	3 days	6 days
	Percent	Percent
<b>Checks:</b>		
Dry (no treatment) .....	30.6a	83.5a
Wet (70° F. water) .....	21.9 b	80.6a
<b>Hot-water treatments</b>		
115° F. water for—		
2.5 min .....	5.6 c	22.5 c
5.0 min .....	4.0 c	19.6 c
125° F. water for—		
2.5 min .....	6.0 c	10.4 cd
<b>Hot-air treatments</b>		
125° F. air 95 pct. RH for 30 min ...	2.9 c	12.9 cd
105° F. air for 24 hours		
and relative humidity <sup>2</sup> —		
37 pct .....	3.8 c	45.4 b
80 pct .....	2.1 c	4.0 d
89 pct .....	.6 c	4.0 d
97 pct .....	0 c	5.0 d

of 8 tests with 15 to 20 fruit per treatment. Means are compared Duncan Multiple-Range Test. In the individual columns, means by a letter or letters in common are not significantly different at the level.

<sup>2</sup>gs on relative humidity made with hygrometer indicator.

Table 3.—Decay at 65° F. of peaches inoculated with *Rhizopus stolonifer* 24 hours before treatment<sup>1</sup>

Postharvest treatment	Decay during—	
	3 days	6 days
	Percent	Percent
<b>Checks:</b>		
Dry (no treatment) . . . . .	87.5a	95.0a
Wet (70° F. water) . . . . .	77.5a	89.4a
<i>Hot-water treatments</i>		
115° F. water for—		
2.5 min . . . . .	9.3 b	28.1 c
5.0 min . . . . .	2.3 b	18.1 cd
125° F. water for—		
2.5 min . . . . .	2.1 b	13.5 cd
<i>Hot-air treatments</i>		
125° F. air 95 pct. RH for 30 min . . .	1.3 b	17.9 cd
105° F. air for 24 hours and relative humidity <sup>2</sup> —		
37 pct . . . . .	8.4 b	48.4 b
80 pct . . . . .	1.6 b	6.9 d
89 pct . . . . .	.6 b	6.3 d
97 pct . . . . .	1.3 b	12.9 cd

<sup>1</sup> Means of 8 tests with 15 to 20 fruit for each treatment. Means are compared by the Duncan Multiple Range Test. In the individual columns, means followed by a letter or letters in common are not significantly different at the 5-percent level.

<sup>2</sup> Readings on relative humidity made with hygrometer indicator.

holding at 65°, however, differences in decay developing on fruit given some of the different treatments were very apparent.

Fruit treated in 105° F. air with relative humidity of 80 percent and above for 24 hours and held for 6 days at 65° developed significantly less decay than when the relative humidity was low during the same exposure period. These 24-hour exposures to high humidity 105° air usually reduced the development of decay more, though not significantly more, than the 125° water or air treatments. Though fruit treated with 125° water developed less decay than those treated in 115° water, the difference in decay

was not significant. Fruit treated with 105° air of low relative humidity developed significantly less decay than either check but significantly more decay than other treatments if held for 6 days after treatment.

### **Fruit Temperature in 105° F. Air**

In five or eight tests air temperature within each of the drums was about  $105^{\circ} \pm 2^{\circ}$  F. within 4 hours of the start of the tests. After the original rise in temperatures, the temperatures within the drums remained relatively constant. Temperatures of peaches increased more slowly. Within an hour these temperatures increased from about 70° to over 85° and then rose at a slow but constant rate until after 12 hours when fruit temperatures near the pit averaged  $103^{\circ} \pm 2^{\circ}$ . They remained at this temperature for the rest of the 24-hour period.

In the other three tests air temperatures rose more rapidly in the drums, and after 12 hours they averaged  $110^{\circ} \pm 2^{\circ}$  F. Temperatures of fruit in these tests increased accordingly and during the final 12 hours were about 3 degrees above the desired 105°.

While the peaches were held in drums in high humidity air of about 105° F., pulp temperatures in the various replicates varied considerably, especially during the final 19 hours. During this period pulp temperatures of some lots of fruit averaged 102° whereas other lots averaged up to 108°. Decay of fruit after transfer to 65° was about the same regardless of the pulp temperature of the fruit during the hot-air exposure.

Temperature of the peaches in ambient air (37 percent RH) in the 105° F. room apparently increased more slowly. After a 24-hour exposure, the fruit temperature just under the skin averaged 94.8°. Temperature under the skin of the fruit in the various tests ranged from a high of 100° to a low of 91°.

At the end of the tests, readings were made on the relative humidity in the three drums at 105° F. The mean of these readings was 80.4 percent, 89.8 percent, and 97.3 percent relative humidity.

### **Appearance and Ripening of Peaches**

Injury in the form of tan spots, streaking, or mottle sometimes occurred on a few peaches of each variety given each heat treatment except those treated in 115° F. water for 2.5 minutes. Normally, the injury detracted only slightly from the general

appearance of the fruit in the particular treatment. Peaches treated in 125° air for 30 minutes were injured most often. Sometimes this injury was severe enough to detract from the general appearance of the fruit. The fruit held in 105° air of high relative humidity for 24 hours usually closely resembled the check fruit. Ground color or red blush was no different between these fruit and the unheated fruit. However, fruit held at 105° in low ambient relative humidity always was badly shriveled.

Peaches treated with hot water, or 125° F. air and then placed at 65° air, ripened at about the same rate as the unheated peaches. During the first 24 hours, the pressure test of the unheated peaches at 65° changed from about 6.8 to 2.3. Fruit held at 105° also ripened. When peaches were removed from 105° air, the pressure test had changed from about 6.8 to 2.7 for fruit held at 37 percent relative humidity, 3.2 at 80 percent, 3.5 at 89 percent, and 3.7 at 97 percent. When these fruits were transferred to 65° within 2 days, they were the same pressure test as the unheated fruit.

## DISCUSSION

Prevention of or reduction in development of decay on inoculated fruit depends on the effectiveness of a treatment in destroying decay-producing organisms on and under the skin of the fruit. In these studies the fruit artificially inoculated 24 hours before treatment resembled fruit inoculated in the orchard 24 hours before harvest. In both inoculations, spores of the brown rot organism would have time to germinate and penetrate beneath the fruit skin. In tests on cherries treated with benomyl suspensions at 70° F., good control of decay was obtained on fruit held 6 days at 65°, but less acceptable control when they were held 9 days. This finding could indicate that the 70° benomyl suspension is toxic to organisms on the surface of the fruit, but organisms under the skin continue to grow and eventually produce external symptoms.

In heated suspensions, on the other hand, benomyl effectively controlled brown rot on cherries after both 6 and 9 days in 65° F. air. This control, however, usually was not significantly different from that obtained with hot water alone. A similar effect was found with heated and unheated suspensions of benomyl to control brown rot of peaches (15).<sup>2</sup> In all experiments, hot-water

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<sup>2</sup> Benomyl is registered for use on peaches and nectarines with a residue tolerance of 15 p.p.m. established. It is not approved for use on cherries.

treatments that were extremely effective in controlling brown rot of cherries held 6 days at 65° air also effectively controlled decay when the fruit was held 9 days at the same temperature. This finding indicates that the water temperature and exposure time were sufficient to destroy the decay-producing organism on and under the skin of the fruit.

In these studies injury to the cherries was difficult to evaluate. Apparently, if cherries have any type of injury, hot-water, heated chemical suspensions, or hot-air treatments are apt to intensify this injury. In limited tests with uninjured cherries, the fruit was seriously injured only when it was exposed to nearly saturated air at 125° F. or when benomyl was used in 125° water. Most of the hot-water or hot-air treatments used in these tests show promise for controlling decay in sweet cherries. These treatments require further testing to better evaluate the causes of injury to the fruit.

Data obtained on hot-air treatments for the control of decay of peaches caused by *Monilinia* confirm the work of Australian researchers (9, 18). These data extend the findings of these researchers by showing the importance of relative humidity during treatment. If the relative humidity during treatment was above 80 percent in about 105° F. air, brown rot and rhizopus rot development on peaches was reduced about equivalent to the best hot-water treatments. Treating sweet cherries in hot air also gave good control of decay. In the studies reported here, control of decay was equally good following treatment in 105° air at relative humidities of about 80, 89, and 97 percent. Some control of decay was obtained when the relative humidity of the 105° room was about 37 percent, but it was not as effective as the high relative humidity and the fruit shriveled.

The exact effect of relative humidity on prevention of decay is difficult to determine. In the experiments reported on here, complications developed when fruit with a pulp temperature of 70° F. was placed in high relative humidity air at 105°. Condensation formed on the fruit during the time the fruit was below the dewpoint temperature, resulting in a saturated condition at the fruit's surface. The effect of the relative humidity of the air on decay, therefore, could not be measured accurately. On the other hand, when 70° fruit was placed in air of low relative humidity (37 percent), the fruit's temperature was close to the dewpoint and in a short time exceeded it. Temperature of this fruit did not increase as much as the fruit placed in high relative humidity air. The chief effect of relative humidity was on increasing fruit temperature. For effective control of decay in

fruit, pulp temperatures of 101° and above apparently are necessary. To obtain such temperatures, the relative humidity during the hot-air treatment should be 80 percent or above.

An alternative to the hot-water or chemical treatments for controlling decay in peaches and cherries is to expose the fruit for 24 hours to high-humidity air at 105° F. Bulk bins or field boxes of fruit from the orchard could be placed directly in a high-temperature, high-humidity room for 24 hours and then moved to another room for ripening. Such a procedure may be especially applicable for canning or processing plants. Peaches handled in this way usually have high temperatures throughout, in contrast to hot-water treated peaches that have high temperatures only under the skin. Nevertheless in these tests with small lots of fruit, peaches treated with hot air ripened at about the same rate as fruit not heated. The Australians, on the other hand, found more rapid ripening in large lots of hot-air treated peaches and recommend that fruit so treated should be cooled to 75° as quickly as possible (personal correspondence).

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